Second Expedition to Yakutat Bay, Alaska.

RALPH S. TARR,
Professor of Dynamic Geology and Physical Geography,
Cornell University.

(Reprinted from the "Bulletin" of the Geographical Society of Philadelphia, January, 1907.)

Second Expedition to Yakutat Bay, Alaska.[1]

RALPH S. TARR.

Professor of Dynamic Geology and Physical Geography,
Cornell University.

Yakutat Bay has been visited by more geographical expeditions than any other point on the Alaskan coast, with the possible exception of Muir Inlet. This fact is due to two causes: (1) Because the great ice plateau of the Malaspina Glacier has offered an excellent route for approach to Mount St. Elias by parties endeavoring to ascend that peak; (2) because the Malaspina and other glaciers have features of unusual interest to students of glaciers and glacial action.

Several expeditions, having for their object the ascent of Mount St. Elias, have crossed the Malaspina Glacier from the ocean side. This was the route chosen by Professor Russell on his second expedition (1891); but on his return he skirted the margin of the Malaspina on both the Pacific and Yakutat Bay sides. In his first expedition (1890), however, Professor Russell made his start from Yakutat Bay. In 1897 two expeditions, one under the direction of Prince Luigi Amadeo, Duke of the Abruzzi,[2] the other in charge of Mr. Henry G. Bryant

[1] Published by permission of the Director of the United States Geological Survey. I take this opportunity of expressing my appreciation of the valuable assistance rendered me in 1905 by Lawrence Martin and B. S. Butler; and in 1906 by B. S. Butler, O. von Engeln, J. L. Rich and R. R. Powers.

[2] The Ascent of Mount St. Elias. By H. R. H. Prince Luigi Amadeo di Savoia, Duke of the Abruzzi, 1900.

of Philadelphia, crossed the Malaspina Glacier from the Yakutat Bay side, entering at the Osar River near the mouth of Yakutat Bay.

All these expeditions have contributed to our knowledge of the remarkable glacial phenomena of the St. Elias region, but none have equaled in this respect the results published by Professor Russell.[3] One fact established by all the expeditions is that the Malaspina Glacier formed an excellent highway for travel, being admirably adapted to sledging, and consequently to the support of a party engaged in extensive exploration.

Besides the Malaspina Glacier and its numerous tributaries from the high mountains, the Yakutat Bay region possesses many smaller glaciers, three of which descend to the bay and discharge icebergs into it. The largest of these, the Hubbard Glacier, has a much longer ice cliff rising above the fiord than that of the Muir Glacier. One of the published results of Russell's expeditions was a description of the glacial phenomena of Yakutat Bay. The Harriman expedition of 1899 also entered the bay, and the work of Dr. G. K. Gilbert forms an important contribution to our knowledge of the glaciers and glaciation of this interesting region.[4]

My own studies in and around Yakutat Bay began in the summer of 1905, when I had charge of an expedition sent by the United States Geological Survey for the purpose of further investigation of the geology and physiography of Yakutat Bay and vicinity. The results of this expedition[5] led to a desire to continue the investigation westward along the base of Mount St. Elias, following Russell's route of 1890 for part of the distance, then striking westward to the western margin of the Malaspina Glacier. The crossing of the Malaspina from east to west had never been undertaken, but it seemed to be perfectly feasible, the only possibility of failure apparently being on the western side, where the glacier comes down to the sea and forms the ice cliff of Icy Cape. Concerning this

[3] Nat. Geog. Magazine, Vol. III, 1891, pages 53-203; Thirteenth Annual Report U. S. Geol. Survey, 1891-2, Part II, pages 1-91.

[4] Harriman Alaska Expedition, Vol. III, Glaciers, 1904, pages 45-70.

[5] Tarr and Martin, Bulletin Amer. Geog. Soc., Vol. XXXVIII, 1906, pages 145-167.

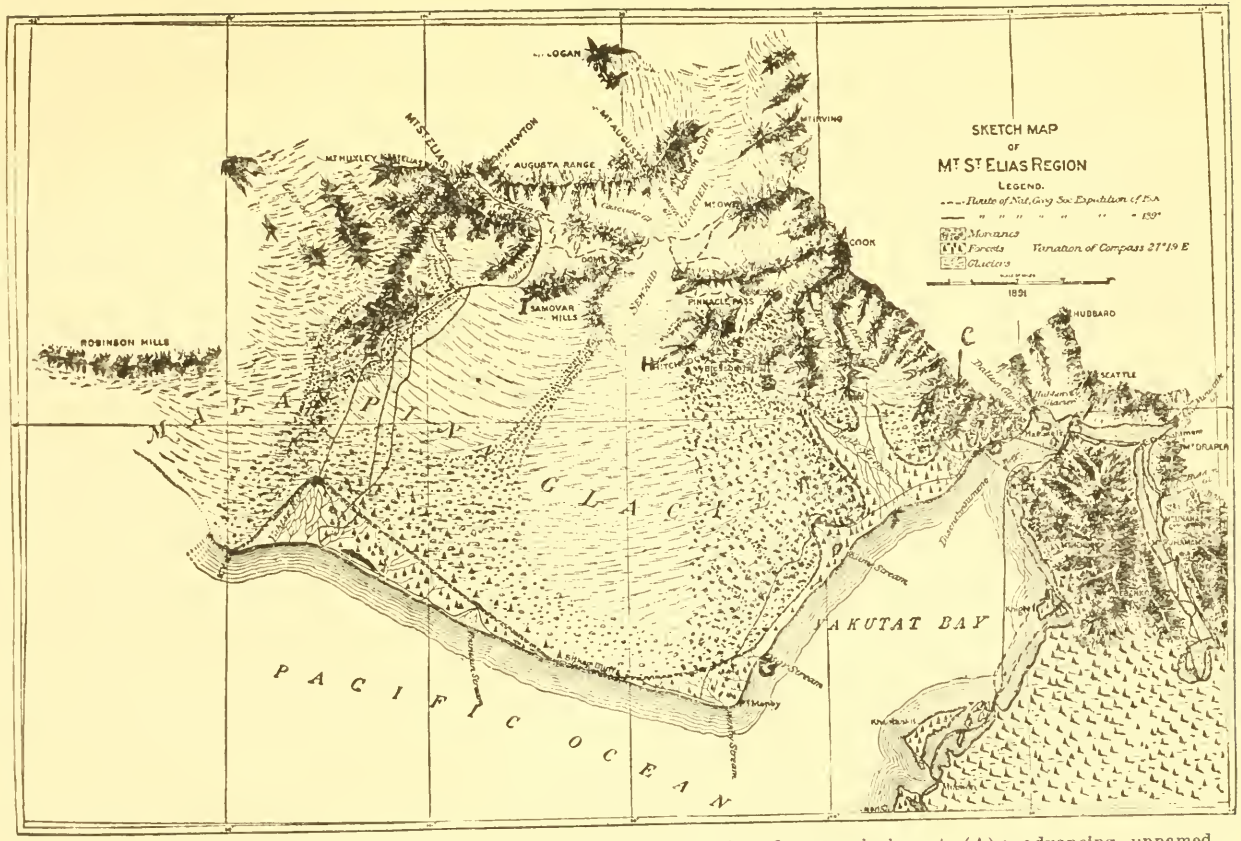

FIG. 1. Professor Russell's map of Malaspina glacier. Advancing Orange glacier at (A); advancing unnamed glacier near Turner (Dalton) glacier at (B); advancing Atrevida glacier at (C); advancing Marvine glacier dotted. Russell's route in 1890 shown by broken line; our route as proposed lay along this from (D) to (E), thence westward past (H) and (I). Route actually followed from (F) to (E) with a trip back to (K). Abruzzi went from (G) to (H) and Bryant from (G) to (I). At present ice between (G) and (F)—the route followed by Russell in 1891—is impassable.

part of the glacier, I was unable to obtain definite information; but the rest of the route had been explored, and possibility of failure there was not even considered. Nevertheless, owing to the remarkable changes recorded below, this part of the route, which in previous years had been so easily traversed, interposed an insuperable obstacle to the proposed crossing of the Malaspina Glacier.

With a party of thirteen associates and packers, six of the latter Indians, I was landed on the eastern side of Yakutat Bay early in the morning of June 23, 1906. The first few days were spent in moving camp to the west side of the bay and in making preliminary arrangements for starting on our journey over the ice. As soon as this was done, I started with one companion on a reconnaissance trip of several days, to lay out in detail the route to be followed in packing our outfit across to Blossom Island, intending while this packing was going on to make a trip up the bay in order to complete some observations begun the previous summer. The route upon which we started was almost exactly that which Professor Russell had followed in 1890. Moreover, in the summer of 1905 I myself had gone over a part of the route (nearly across the Atrevida Glacier), and had sent two of my party, Messrs. Butler and Martin, across the Atrevida and Lucia Glaciers and through Floral Pass to the Hayden Glacier. Thus, in August, 1905, we knew this route to be a perfectly feasible one for packing, and had no expectation of any material change in so short a period.

Judge our surprise, therefore, when approaching the edge of the Atrevida Glacier, to find that it had changed absolutely in a period of ten months. The margin facing Yakutat Bay, which in August, 1905, was moraine-veneered ice of moderate slope, up which we easily walked, was now a vertical ice cliff crowned with jagged pinnacles and cleft by deep crevasses. The ice tunnel from which the glacial stream had emerged was now further toward the sea by over a hundred yards; the ice was advancing into the forest; and the alder thicket, which covers the lower end of the glacier, was torn by great rents into which the moraine and vegetation were falling. From the steep ice front stones were constantly rattling down, burying

FIG. 2. A view over the moraine-covered surface of the Atrevida glacier, August 20, 1905. Taken near middle of glacier to show an exceptional area of crevassing, then interpreted as due to a buried rock hill, but now believed to represent a first stage in the great advance which has since occurred. Compare with Fig. 3.

FIG. 3. Photograph (with long-focus lens) to show sea of crevasses in Atrevida glacier. Looking eastward across the Atrevida glacier from Terrace Point, August 2, 1906. The view in Fig. 2 was taken from a point about half way across the glacier, looking toward the camera station of Fig. 3. On August 20, 1905, the only notable crevassing in this entire area was that shown in Fig. 2.

the forest beneath morainic debris; the ice cliff was broken by thrust faults; great blocks of ice were occasionally falling from the front, so that even an approach to the cliff was dangerous; and the ascent of the cliff could be made only by great labor and with the aid of ice axes.

Our entrance along the route which we had so easily followed the previous summer was thus completely cut off. Thus barred, we turned back in amazement which amounted almost to stupefaction. It seemed utterly incredible; and, so far as I can now tell, such a change is entirely unprecedented. Thinking that there might perhaps be some other route by which we could enter upon the ice, and that possibly by some roundabout course we might cross the Atrevida Glacier, we went the next day to the crest of a low mountain which rises directly above the eastern side of the Atrevida Glacier. From this point of view, which overlooked the entire Atrevida, it became evident that there was no route across this glacier by which we could hope to pack our outfit; and, in fact, it seemed probable that even a party unburdened could not hew its way across.

In 1905 this glacier consisted of three parts: (1) A stagnant expanded ice foot, outside of the mountains, which was covered with a dense alder growth; (2) an upper valley portion nearly clear of morainic debris, and only slightly crevassed; and (3) an intermediate portion of moraine-covered ice on which there was very little vegetation in the form of scattered alders and willows. In 1906 the clear upper portion was pinnacled by crevasses and melting; the intermediate portion was broken by a sea of crevasses into which more than half of the morainic veneer had tumbled, revealing the clear ice where in 1905 there was practically none in view; and the alder-covered end, a bulb-shaped area at least twice the width of the glacier in its valley portion, was broken by a series of concentric crevasses revealing rings of clear ice in the alder thicket.

Over beyond the Atrevida Glacier the Lucia could be seen coming out of its mountain valley from the base of Mt. Cook, sweeping past Terrace Point and coalescing with the crevassed and altered Atrevida. So far as could be seen from the mountain top, the Lucia Glacier had not changed since it was crossed

by our party in August, 1905; and later explorations proved this to be the case. Thus there are two neighboring and coalescing glaciers, one of which shows a remarkable and unprecedented breaking, while the other has suffered no perceptible change.

Baffled in our attempt to follow the route chosen, we decided to go around the end of the Atrevida Glacier, along a more difficult route, up the valley of the Kwik River, the great glacial stream which carries the waters from the Marvine, Hayden and Lucia Glaciers. If this route could be followed it would take us along the path originally chosen, with the exception of the first portion of it, and the larger part of that could be visited by a backward journey across the Lucia Glacier to the western margin of the Atrevida Glacier. Accordingly, directions were given to the packers to move the camping outfit to the Kwik Valley, and to carry our supplies up that valley to the Hayden Glacier, where we expected to be able to begin sledging.

In the meantime, my scientific associates[6] and I made a boat trip up Yakutat Bay to the head of Russell Fiord. Here we found a remarkable change in two of the glaciers since our visit the previous year.[7] The Turner Glacier was in approximately the same condition as in 1905, but a small unnamed glacier a quarter of a mile north of the Turner had suffered a remarkable change. Late in August, 1905, it terminated some distance from the sea in a moraine-covered, apparently stagnant end. It was then wholly separated from the Turner Glacier; and its lower portion was completely covered by black shale fragments. By June, 1906, this glacier had advanced into the sea, spreading out fan-shaped and coalescing with the Turner Glacier, thus extending the continuous ice cliff of the Turner Glacier at least a mile to the northeast. This new addition to the Turner Glacier ice cliff is badly crevassed, and the ice back of it is also broken and pinnacled; but the surface is still well blackened by its morainic veneer.

About a half mile further north is another glacier similar

[6] Messrs. B. S. Butler, J. L. Rich, O. von Engeln, and R. R. Powers.

[7] For a map showing the glaciers of this bay see Bull. Amer. Geog. Soc., Vol. XXXVIII, 1906, opposite p. 145.

to this one. But it has not changed perceptibly since 1905, and still ends some distance from the water.

The Hubbard Glacier, the next up the fiord, seems to have advanced slightly, if at all; but until we can compare our photographs, it is impossible to make exact statements on this point. Just east of the Hubbard, however, there is a glacier which has changed remarkably. This we named the Orange Glacier in 1905, and gave to it a rather careful study because of the fact that the morainic phenomena on its stagnant, bulb-shaped terminus were of unusual interest. In August, 1905, we walked freely over this bulb-shaped terminus and ascended the Orange Glacier to a distance of five or six miles from the sea. It has changed absolutely; the interesting concentric moraines are completely destroyed; the ice is profoundly crevassed; and it was not found possible even to enter upon this glacier which in 1905 was easily traversed from the sea up to the snow line. No other glaciers in the fiord show any notable change.

On our return from the trip up Yakutat Bay, we proceeded to the mouth of the Kwik River, up which our packers had been carrying provisions and necessary camping outfit, including a sled, which we expected to use in crossing the Malaspina. We found that our packers had made fairly good progress, having our supplies moved to the base of the Hayden Glacier. But the work had been difficult and necessarily slow. The Kwik is made by the union of two very large and swift glacial streams to which are added many smaller ones. It quickly branches and subdivides into a large number of distributaries, spreading completely over a broad alluvial fan. The packers were obliged to cross scores of these branches, some of them of such swiftness as to render the crossing difficult and even dangerous. The streams were ever changing in position and in depth, so that at no two trips were the conditions the same. Added to the difficulties of fording miles of glacial waters was the presence of quicksands in the lower course of the Kwik.

The treacherous character of the Kwik River was brought clearly to our attention by an accident which came very near bringing an end to our exploration in its very earliest stages.

The packers had cached most of the provisions and camping equipment near the banks of a moderately large distributary of the Kwik in what seemed to be a perfectly safe position. Early in the morning, as they approached this cache to move it across to the other side of the stream, they saw it tumbling into the river. Much of the material was saved, but a great deal was lost. That which we missed and mourned the loss of most was fifty pounds of Wilbur's milk chocolate, which we had taken along for luncheons when on the march. Later we found that this disaster was probably due to the bursting of an ice-dammed lake in the headwaters at Blossom Island.

By the time we had come up with the packers, it had become evident that our crossing of the Malaspina Glacier was probably not to be accomplished. The margin of the Malaspina, which forms the western side of the Kwik Valley, and whose supply of ice is derived from the Marvine Glacier tributary, was found to be greatly crevassed and broken by a recent movement similar to that previously discovered in the glaciers mentioned above. This crevassing was found to extend southwestward along the shores of Yakutat Bay, as far as could be seen from the mouth of the Kwik. Later exploration along this coast as far as Point Manby showed that the crevassing extends at least that far. It is along this ice front, sometimes on the ice, sometimes on the moraine in front of it, that Professor Russell made his retreat to the entrance of Disenchantment Bay in 1891. His march was made with no great difficulty; but at the present time such a journey would be entirely impossible. Our later visit to Point Manby proved that the route by which the Duke of Abruzzi and Mr. Henry G. Bryant entered upon the Malaspina Glacier, is now closed. The entire face of the ice is now frightfully broken and crevassed.

Where we skirted the margin of the Malaspina Glacier, close at hand, as we did along the western side of the Kwik Valley, we found that the crevassing was still in process of development during our visit. During many years of stagnation the ice had become buried beneath a thick covering of morainic debris, forming a soil in which alder and cottonwood

FIG. 4. The Orange glacier from the moraine-covered ice of the outer part of its bulb-like expansion, August 8, 1905. The view looks across an alluvial fan built in a depression on the ice. A glacial stream emerges from a rock gorge. Behind it rises moraine-covered ice, and behind that (on the left) the winding Orange glacier which is so smooth that we walked up to the bend in the distance in a half day.

FIG. 5. Photograph, August 17, 1906, from nearly same point as Fig. 4 (about seventy-five feet lower, and a few hundred yards further to the left). The Orange glacier is now crevassed at least as far as the bend. Its moraine-covered terminus is very much higher and nearer. It has advanced over and buried the rock gorge, and a stream no longer emerges at this point. Much clear ice is shown in the crevassed bulb where a year before from this distance no ice whatsoever was visible through the moraine.

thickets had taken root. In the spring of 1906 the alder and cottonwood trees developed their leaves as usual; but for many of them it was their last spring season. The forward thrust has broken the ice into blocks, separated by yawning chasms, into which large numbers of the trees have fallen. Many of these had the color of autumn, but none, so far as we could see, had failed to develop leaves before their uprooting. We assume, therefore, that the forward thrust and breaking of the ice had its beginning after the leaves were developed.

That this part of the Malaspina Glacier was advancing during our visit, we had abundant evidence. Fragments of ice fell from the front as we passed it; the morainic soil was constantly sliding down the ice front and into the crevasses; muddy glacial torrents were developing where none had existed before; again and again trees were seen to fall; and in the month which elapsed between our first passage of this ice margin and our return, the face of the glacier was absolutely changed in detail.

From a low mountain top near the eastern margin of the Malaspina Glacier, we were able to get a bird's-eye view of its eastern half, from the sea back to the mountain base. From here it became evident that the only chance of getting to the western side of the Malaspina Glacier lay in a possible route past Blossom Island up the margin of the Marvine Glacier, and thence along the mountain base to the west. There seemed little hope of even this, however, for as far as we could see up the valley of the Marvine there was a perfect sea of crevasses; and from this point down to Yakutat Bay and Point Manby the Malaspina Glacier was completely impassable for packing purposes at all points.

We pushed on to Blossom Island across the Hayden Glacier, which shows no change from its condition in 1905. And from Blossom Island we made a trip back across the Hayden Glacier through Floral Pass and across the Lucia Glacier to Terrace Point, at the western margin of the Atrevida Glacier. From this point our first observations, which were made on the eastern side of the glacier, were amply verified. No one could now possibly cross this glacier with sup-

plies, although in the preceding summer there was no greater difficulty in crossing it than there was in 1906 in crossing the Lucia Glacier.

From the summit of Blossom Island, and from a short trip as far up the margin of the Marvine Glacier as we could go, we saw plainly that that route westward was also cut off. This short excursion was along the path which Russell followed in his first attempt to ascend Mount St. Elias. He mentions no special difficulties in his way in this part of the journey, and from the rapidity of his march, as well as from his description, it is evident that the conditions of to-day were not then present. He could not have carried his supplies up the margin of the Marvine Glacier, nor could he have crossed the glacier where he did had the conditions approached those of 1906.

Our view from the summit of Blossom Island showed clearly not only the condition of the Marvine Glacier, but of the Seward Glacier where it comes out of its mountain valley and spreads out to join the Marvine, forming the eastern part of the Malaspina ice plateau. This glacier is not crevassed to the extent that the Marvine is, but nevertheless it is decidedly broken, and from a distance looks impassable. Benno Alexander, a member of my party, was with the Duke of Abruzzi on his ascent of Mount St. Elias, and he states that from the view which he obtained from the summit of Blossom Island, he is convinced that the Seward Glacier is decidedly changed from its condition in 1896. He sledged over this route again and again, but, as viewed from the summit of Blossom Island the glacier seems now to be in such a condition as to making sledging over it impracticable. The Seward Glacier, therefore, seems to be advancing, but its advance has not proceeded far enough to so completely break that part of the Malaspina which it supplies as the advance of the Marvine has done to its lobe of the Malaspina. It will be interesting to know whether this apparent advance of the Seward Glacier continues, and whether its effect in the next year or two is felt down to the sea.

That there has been a remarkable change in some of the glaciers of the Yakutat Bay region there is no question. That

this change has for the most part, if not entirely, occurred during the past year, is clearly proved by our comparative observations of 1905 and 1906, which include all the glaciers that have advanced, excepting the Marvine, which we did not actually visit in 1905. Even in this case, however, we examined the glacier from a distance with field glasses and failed to detect any notable crevassing, although in 1905, from the same points of view, the broken condition of the glacier was very evident. It is certain, too, that this change is still in progress, the wave of advance not yet having died out.

The recent forward movement recorded in these glaciers is spasmodic and of decided extent, being sufficient not merely to break up glaciers enclosed in mountain valleys, but also to introduce crevassing in a broadly expanded ice foot which has been so nearly stagnant, and for such a long time, as to permit the accumulation of a deep morainic soil, and, near the margin, the growth of trees a full half century old.

In accounting for this phenomenon the above facts must be explained; and, in addition, it is necessary to account for the fact that, while some glaciers are thus affected, others, even the nearest neighbors, have not yet been influenced by the cause which has produced the wave of advance. Moreover, it is necessary to take into consideration the fact that some of the advancing glaciers are very small and short, others large and long. In seeking an explanation for these remarkable changes, there is, so far as I am aware, no guide from previously described occurrences. The advance seems to be totally different from those which are associated with climatic variations, by which a slow forward movement is caused without further notable changes in the glacier.

All excepting one of the possible explanations that we have been able to suggest have been considered and discarded as incapable of explaining the facts. The single hypothesis against which no facts are opposed, and which seems the most rational explanation of the phenomenon, is that of earthquake effect. In the autumn of 1899 this region was visited by a succession of earthquake shocks of exceptional vigor, during which the coast line was uplifted throughout most of the area

of Yakutat Bay, the uplift of the coast in one place having been more than forty-seven feet.[8] During this earthquake the region was violently shaken not only once, but many times; and, from the descriptions of eye-witnesses, as well as from evidences which are still apparent, it is certain that in many places great masses of rock were thrown down the mountain-sides as avalanches. There must also have been a great down shaking of snow and ice from the steep slopes among which these glaciers were fed.

The hypothesis which is proposed to account for this advance of the glaciers is that during the earthquake an exceptional mass of snow was caused to descend into the valleys of the glaciers in the Yakutat Bay region. This great accession of snow supply started a marked wave of advance in the glaciers, which has broken up the rigid ice into the condition of the present, and has been sufficiently powerful to push forward and break up the bulb-shaped terminus of several of the glaciers. The reason why some glaciers do not show the effect of this impulse may be sought in two directions: First, in some cases the wave has not yet reached far enough down to produce the effect which has just arrived in those glaciers described; secondly, some glaciers did not have the necessary kind of slopes and amount of snow in unstable condition to bring about a sudden forward movement.

This explanation of the phenomenon as an earthquake result at first sight seems to demand a more rapid forward movement of the wave than would be expected from our knowledge of waves of advance related to climatic variations. It is, indeed, considered possible that the advance at present in progress is not related to the earthquake of 1899, but to some previous shock of equal or greater violence. On this point we have no facts to present; but it should be noted that the wave of advance in this case is quite different from that observed as the result of climatic variations. This may be illustrated by reference to a specific case. The Atrevida Glacier has in nine months been completely broken from near its head almost down to its terminus, a distance of not less than six or

[8] Tarr and Martin, Bull. Amer. Geol. Soc., Vol. XVII, 1906, pages 29-64.

FIG. 6. The ice cliff (on the right) at the margin of the Atrevida glacier, July 10, 1906. From this broken ice point stones and blocks of ice were constantly falling and the forest is being destroyed.

seven miles. The entire appearance is that of a great shove from behind, breaking a rigid and resisting ice mass in front. In a wave of advance due to ordinary slow climatic variations, the impulse is slowly transmitted down the glacier to its end. But a great wave such as might be expected to result from a sudden and enormous addition of snow to the reservoir, would give an impulse which, applied to the resisting, rigid ice in front, might well cause a spasmodic crushing and forward movement far down the glacier, thus rapidly outrunning the progress of a normal wave of advance.

Our disappointment in our failure to carry out the exploration as originally planned, was largely overcome by our opportunity to study this remarkable change in the glaciers. We spent our time, therefore, in an examination of this phenomenon instead of in a march westward across the Malaspina Glacier; and when this was done we started down the valley of the treacherous Kwik, fording its many threads of ice-cold torrents, passing over its quicksands, and finally crossing the surf-beaten bar which guards the entrance to the mouth of this heavily sediment-laden river.

Naturally, in such an expedition there were many incidents and excitements. Two of these had special bearing upon the expedition, since they caused the destruction of some of our most valuable photographic records. In the first of these, two of us were crossing the Kwik River alone when one was swept off his feet, and started on a journey in the ice-cold torrent toward a glacial tunnel under which the Kwik flows for seven miles. His companion pulled him out, but his camera proceeded on the journey and was never seen again. The second incident, lower down in the Kwik Valley, occurred when six of us were crossing the river together, holding to a stout pole in order to increase our stability in fording the rushing current. The man up-stream was swept off his feet, the next three went down like ninepins, and two of us were rolled on down in the icy current, where we remained for five minutes before, chilled to the bone, we were drawn out by one of the packers. One of us had the misfortune to have upon

his back, among other things in his sixty-pound pack, the entire series of photographs that had been taken in the study of the Malaspina Glacier. Although supposed to be in water-proof packages, these were badly water-soaked and many of them absolutely ruined. Nevertheless, enough were obtained to show clearly the remarkable conditions which have been described.

The Malaspina Glacier has, since its first description by Russell, been one of the best known glaciers and the finest example of a nearly stagnant Piedmont Glacier. In its eastern part it is no longer what it was. It has started upon a new life, the end of which no one can predict. It should be watched with care, for it has many lessons of importance to reveal. It will be of the highest value to students of glaciers and glacial phenomena to have the Malaspina Glacier made the basis of a study each year for the next few years, or until such time as the present forward movement has ceased.

FIG. 7. Margin of the Malaspina glacier on the west side of the Kwik Valley, August 11, 1906. The broken blocks are ice fragments produced by the forward movement and breaking of the glacier margins. Note the tumbled trees (in leaf) on and in front of the jagged ice cliff.